ISSN: 0975-833X

Available online at http://www.journalcra.com

International Journal of Current Research
Vol. 9, Issue, 05, pp.51642-51645, May, 2017

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

RESEARCH ARTICLE

EFFECT OF VARIOUS OPERATING CONDITIONS ON THE COOLING PERFORMANCE OF TRANSCRITICAL ORGANIC RANKINE REFRIGERATION SYSTEM

[1]Ankit Tiwari, [2,]*Mohan Gautam, [3]Kuldeep Chauhan, [4]Gopal Fartyal, [5]Sunny Singh and [6]Vivek Kumar Chahar

[1]Ph.D. Scholar, Amity University Haryana, India
[2,5,6]B.Tech, Department of Mechanical Engineering, Amity University, Haryana, India
[3]B.Tech, Department of Electronics & Communication Engineering, MDU, Rohtak, India
[4]B.Tech, Department of Electronics & Communication Engineering, Amity University, Haryana, India

ARTICLE INFO

Article History:
Received 07th February, 2017
Received in revised form
14th March, 2017
Accepted 15th April, 2017
Published online 31st May, 2017

Key words:

ORVC System, TORVC System, System COP, Waste heat, Working fluid.

ABSTRACT

Organic Rankine vapour compression (ORVC) refrigeration systems using waste heat are well known in the literature. In last year's, transcritical organic Rankine vapour compression (TORVC) systems are proposed to increase the system coefficient of performance (COP). This paper presents the parametric simulation results and the performance analysis of TORVC refrigeration system utilizing waste heat using R134a as working fluid under different operating conditions such as evaporation/condensation temperature and degree of superheating/sub-cooling. Heat-to-electrical energy conversion efficiency is also taken into account. System COP is defined using not only the heating energy required for the refrigerant but also electrical energy input to the pump. As waste heat one can consider also exhaust heat of the vehicles. Variation of system COP for different evaporation/condensation temperatures and the degree of superheating/sub-cooling are demonstrated. In the calculation refrigerant temperature and pressure at the heat source are taken as 180oC and 8 MPa.

Citation: Ankit Tiwari, Mohan Gautam, Kuldeep Chauhan, Gopal Fartyal, Sunny Singh and Vivek Kumar Chahar, 2017. "Effect of various operating conditions on the cooling performance of transcritical organic rankine refrigeration system", *International Journal of Current Research*, 9, (05), 51642-51645.

INTRODUCTION

Most important conservation of natural resources is energy recovery from waste heat. We can get refrigeration all the year where we have waste heat in form of flue gases and exhaust gases. Therefore energy recovery from waste heat for refrigeration purposes is one of the appropriate methods. The coupling of Organic Rankine cycle (ORC) and normal inverse Rankine cycle for refrigeration (vapour compression) can be applied for refrigeration from waste heat. This system can be named as organic Rankine vapour compression (ORVC) system. This system is used by Little and Garimella (Little and Garimella, 2011) for 60^0C and 120^0C waste heat temperatures using R245fa as refrigerant. Similar works are carriedout theoretically (Wang *et al.,* 2011) and experimentally (Wang *et al.,* 2011). Aphornratana and Sriveerakul (Aphornratana and Sriveerakul, 2010) obtained a COP of 0.25 for a generator, condenser and evaporator temperatures of 60^0C, 35^0C and 5^0C, respectively. Jeong and Kang (2004) and Li *et al.,* (2013) analyzed different refrigerants for ORVC systems.

Corresponding author: **Mohan Gautam,**
B.Tech, Department of Mechanical Engineering, Amity University, Haryana, India

For high coefficient of performance (COP), high waste heat sources must be used. For this purpose it is necessary to use transcritical cycles (Yılmaz, 2015). This named transcritical organic Rankine vapour compression (TORVC) system. Refrigerant R134a can be used in most systems, including mobile transport. Therefore, in this work R134a is used. Condensation and evaporation temperatures are very important for system COP. Besides this, the degree of sub-cooling and superheating have influence on the COP. In this work, influence of these parameters is investigated.

System description

The system is shown schematically in figure 1 and figure 2 (Yılmaz, 2015). In the power cycle, the liquid refrigerant pressure is increased to 8 MPa by the pump. These parameters are selected to get optimum condition as shown by (Yılmaz, 2015). The temperature of the refrigerant is increased till 180^0C with waste heat supplied to the heater. The refrigerant produces work in the turbine, which drives the compressor. The refrigerants coming from the compressor and turbine are mixing at point 15 and supplied to the condenser. For the refrigeration purpose, the liquid refrigerant pressure is decreased to the evaporator pressure by the expansion valve. The liquid-vapour mixture is introduced into the evaporator and superheated till point 1. The low pressure vapour is compressed and has the property at point 2. Condenser temperature $T_C = T_4 = T_5$ and the evaporator temperature $T_6 = T_7 = T_8 = T_9$ are the parameters to be investigated. Besides these, the influence of superheating.

$\Delta T_{SH} = T_1 - T_8$

and the influence of sub-cooling

$\Delta T_{SC} = T_5 - T_6$

on the system COP's are investigated.

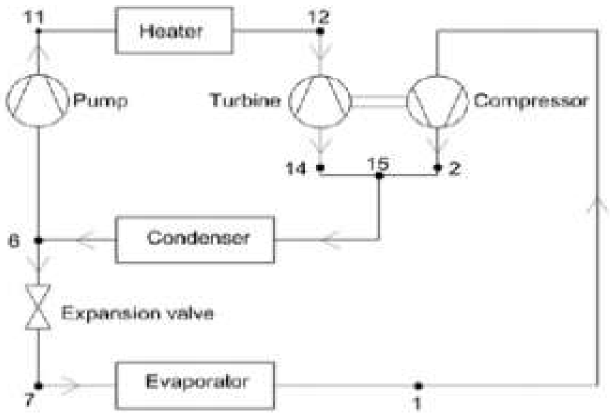

Fig. 1. Schematic presentation of TORVC refrigeration system

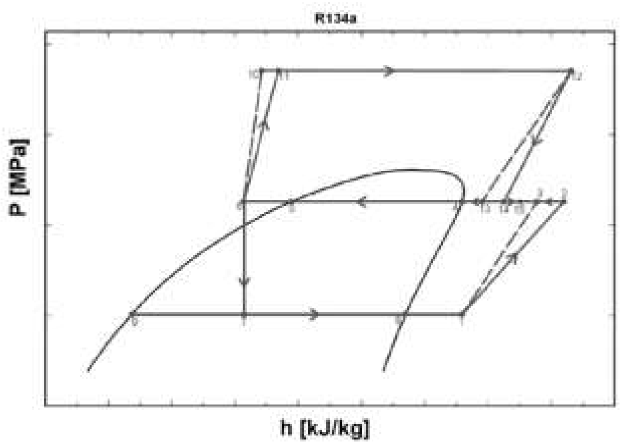

Fig. 2. Schematic presentation of TORVC refrigeration system in p-h diagram

NUMERICAL PROCEDURE

In this work, different COP's are determined.

$$COPH = \frac{w(h_1 - h_7)}{h_{12} - h_{11}}$$

$$COPT = \frac{w(h_1 - h_7)}{\dfrac{(h_{11} - h_6)}{\eta_{pm}\,\eta_{pe}\,\eta_e} + (h_{12} - h_{11})}$$

$$COPW = \frac{w(h_1 - h_7)\,\eta_{pm}\,\eta_{pe}}{h_{11} - h_6}$$

COPH is ratio of evaporator capacity to the heat supplied to the system. COPT takes into account both the heat supplied to the heater and the power supplied to the pump. COPW takes only the work given to the pump into consideration. w means, the ratio of the mass flow rates in the power cycle to that in the refrigeration cycle:

$$w = \frac{\dot{M}_c}{\dot{M}_t}$$

which can be determined from

$$w = \eta_{tc}\,\frac{h_{12} - h_{13}}{h_3 - h_1}$$

With

$$\eta_{tc} = \eta_{ti}\,\eta_{ci}\,\eta_{tm}\,\eta_{cm}$$

RESULTS

In figure 3, 4 and 5; COPH, COPT and COPW values are presented as a function of the condenser temperature T_c. The high, medium and low efficiencies are given as parameters. In these figures, sub-cooling and superheating temperature differences are assumed as $\Delta T_{SH} = \Delta T_{SC} = 5$ degree Celsius. Evaporator temperature is given as $T_e = 10$ degree Celsius.

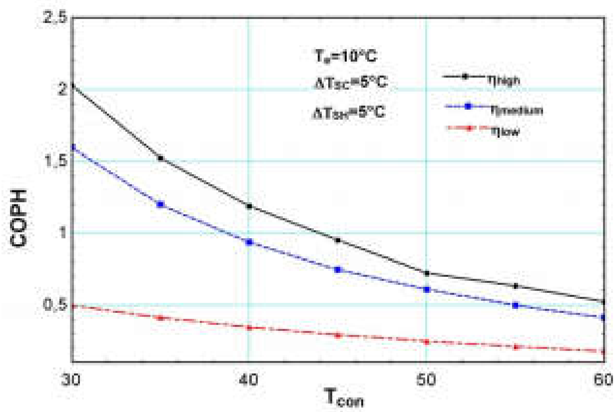

Fig. 3. Influence of the condenser temperature on the COPH for different efficiencies

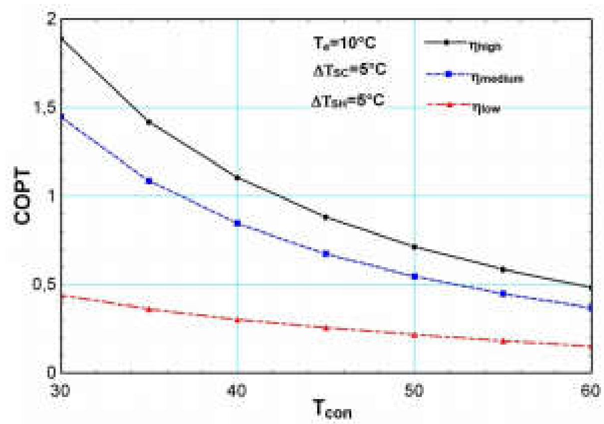

Fig. 4. Influence of the condenser temperature on the COPT for different efficiencies

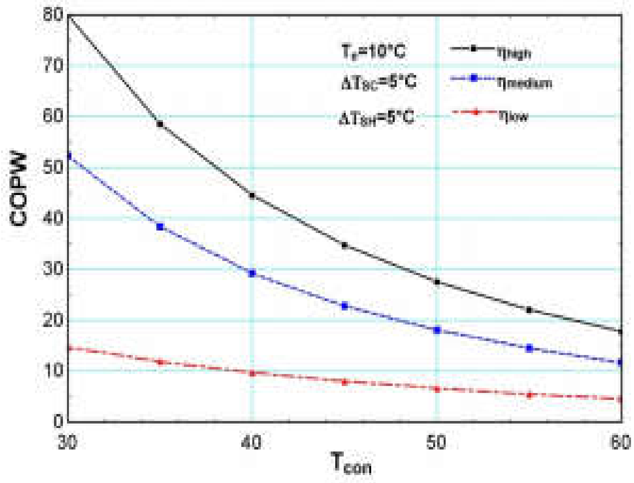

Fig. 5. Influence of the condenser temperature on the COPW for different efficiencies

AllCOP's are decreasing with increasing of condenser temperature. The influence of the values of the efficiencies is also high. In the figures 6, 7 and 8, the condenser temperature remains constant as $T_{c=}50$ degree Celsius and COP's are given dependent of the evaporator temperature T_e. The dependency of theevaporator temperature is high. Similarly, the efficiencies are very important for the COP's.

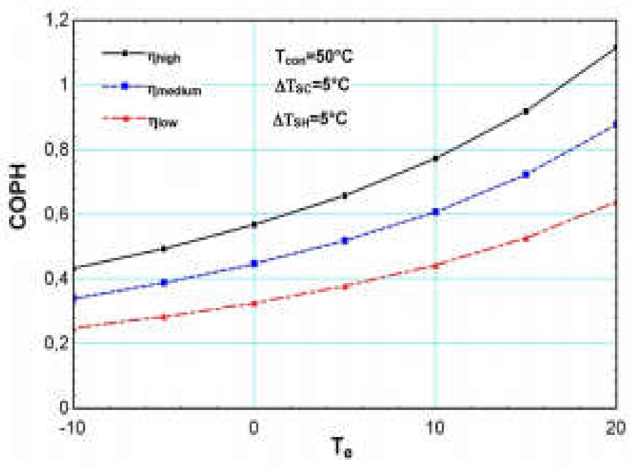

Fig. 6. Influence of the evaporator temperature on the COPH for different efficiencies.

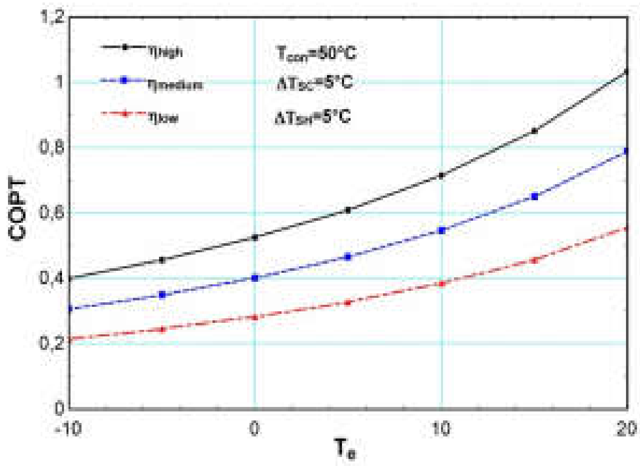

Fig.7. Influence of the evaporator temperature on the COPT for different efficiencies

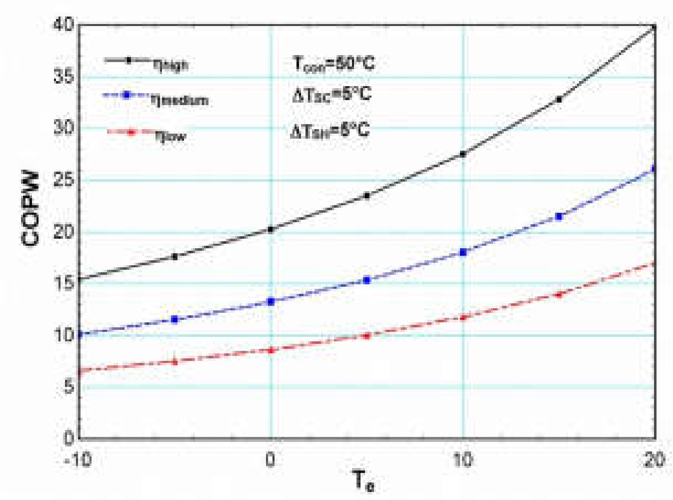

Fig. 8. Influence of the evaporator temperature on the COPW for different efficiencies

In the figures 9 and 10, COP's are given dependent of$\Delta T_{SH}$and ΔT_{SC}. The evaporator and condenser temperatures are given as constant $T_{c=}50$ degree celsius and $T_{e=}10$ degree Celsius respectively. In figure 9, $\Delta T_{SC} = 5$ degree Celsius and in figure 10, $\Delta T_{SH} = 5$ degree celsius are assumed. It is seen from these figures, that, COP's are decreasing withΔT_{SH} but increasing withΔT_{SC}. But the influences are wick and not more than 1% forΔT_{SH} and not more than 13% for ΔT_{SC} in the given superheating and sub-cooling temperature ranges.

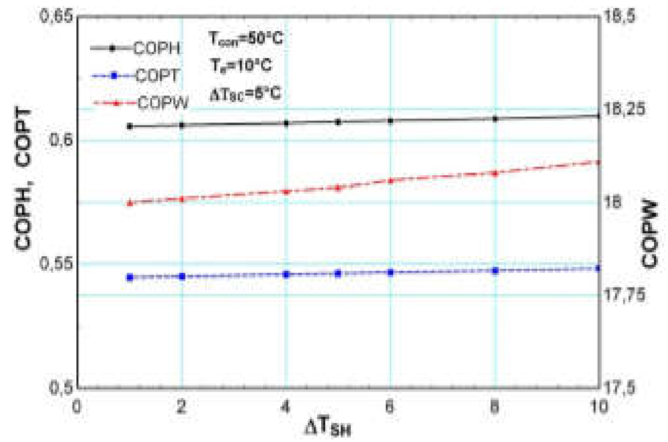

Fig. 9. Influence of the degree of superheating on the COP's

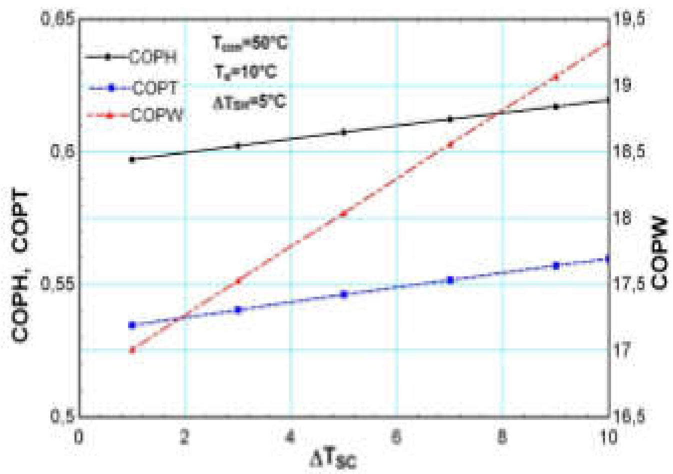

Fig. 10. Influence of the degree of sub-cooling on the COP's

Conclusion

The influence of evaporator temperature, condenser temperature, and the degree of sub-cooling and superheating temperatures are investigated. It is shown, that the dependence of COP's from condenser and evaporator temperatures is very strong. But the dependence of the COP's from sub-cooling and superheating temperatures is very wick. The assumption of high, medium and low values for the efficiencies in turbine, compressor and pump are very important for the COP's.

NOMENCLATURE

COPH COP, eq. (3)
COPT COP, eq. (4)
COPW COP, eq. (5)

h - enthalpy, $kJkg^{-1}$
M refrigerant mass flow rate, kgs^{-1}
P pressure, MPa
T temperature, ^{o}C
w mass flow ratio, eq. (10)
W work, kW
ΔT_{SC} sub-cooling temperature difference, ^{o}C
ΔT_{SH} superheating temperature difference, ^{o}C
η_{tc} turbine-compressor total isentropic mechanical efficiency, eq. (8)
η_{ci} compressor isentropic efficiency
η_{cm} compressor mechanical efficiency
η_{pi} pump isentropic efficiency
η_{pm} pump mechanical efficiency
η_{ti} turbine isentropic efficiency
η_{tm} turbine mechanical efficiency

REFERENCES

Aphornratana, S., Sriveerakul, T. 2010. Analysis of a combined Rankine-vapor-compression refrigeration cycle. *Energy Conversion and Management*, 51: 2557-2564.

Jeong, J., Kang, Y.T. 2004. Analysis of a refrigeration cycle driven by refrigerant steam turbine, *Int. J. Refrigeration,* 27: 33-41.

Li, H., Bu, X., Wang, L., Long, Z., Lian, Y. 2013. Hydrocarbon working fluids for a Rankine cycle powered vapor compression refrigeration system using low-grade thermal energy. *Energy and Buildings*, 65: 167-172.

Little, A.B., Garimella, S. 2011. Comparative assessment of alternative cycles for waste heat recovery and upgrade. *Energy*, 36: 4492-4504.

Wang, H., Peterson, R., Harada, K., Miller, E., Ingram-Gable, R., Fisher, .L, Yih, J., Ward, C. 2011. Performance of a combined organic Rankine cycle and vapor compression cycle for heat activated cooling. *Energy*, 36: 447-458.

Wang, H., Peterson, R., Herron, T. 2011. Design study of configurations on system COP for a combined ORC (organic Rankine cycle) and VCC (vapor compression cycle). *Energy*, 36: 4809-4820.

Yılmaz, A. 2015. Transcritical organic Rankine vapor compression refrigeration system for bus air-conditioning using engine exhaust heat, *Energy*, 82:1047-1056.

****